The Application of Engineered Phytotechnology for Remedial System Optimization and Ultimate Site Closure – Two Case Studies

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Presentation Summary

Brief introduction to *TreeWell*® Technology

- How it works and key benefits
- Risk management considerations

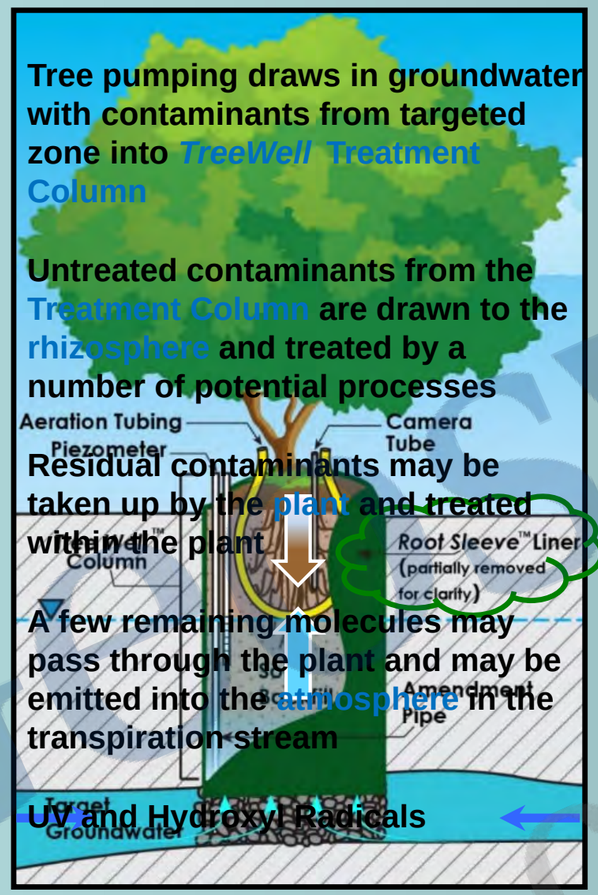
Example projects using *TreeWell* Technology

- Successful applications
- Its use as a replacement for Pump-and-Treat systems

Engineered Phytoremediation with TreeWell® Technology

Geosyntec consultants

The "Pump"



Tree pumping draws in groundwater with contaminants from targeted zone into *TreeWell* Treatment Column

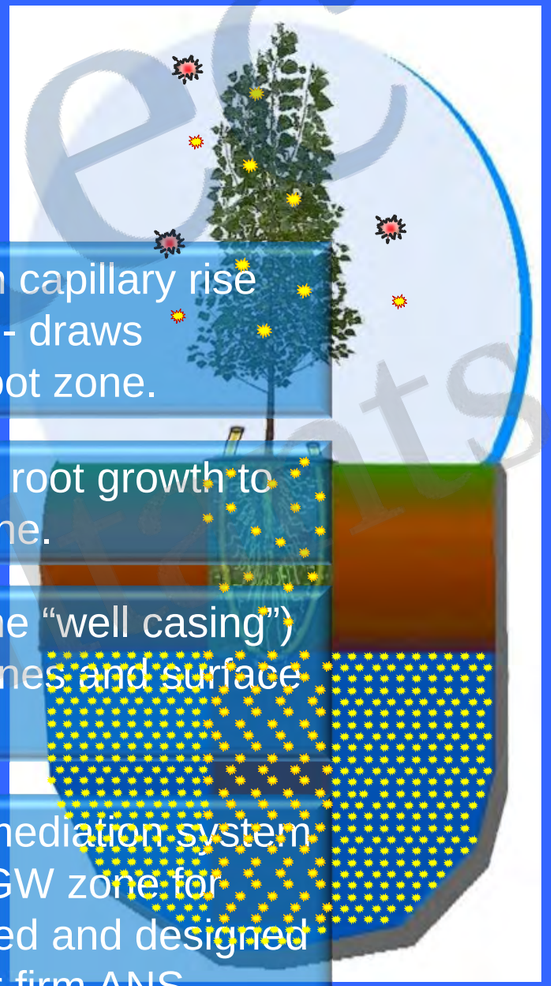
Untreated contaminants from the Treatment Column are drawn to the rhizosphere and treated by a number of potential processes

Residual contaminants may be taken up by the plant and treated within the plant

A few remaining molecules may pass through the plant and may be emitted into the atmosphere in the transpiration stream

UV and Hydroxyl Radicals

"Treatment"



GW enters unit through capillary rise or potentiometric head - draws contaminated GW to root zone.

Encourages downward root growth to the target saturated zone.

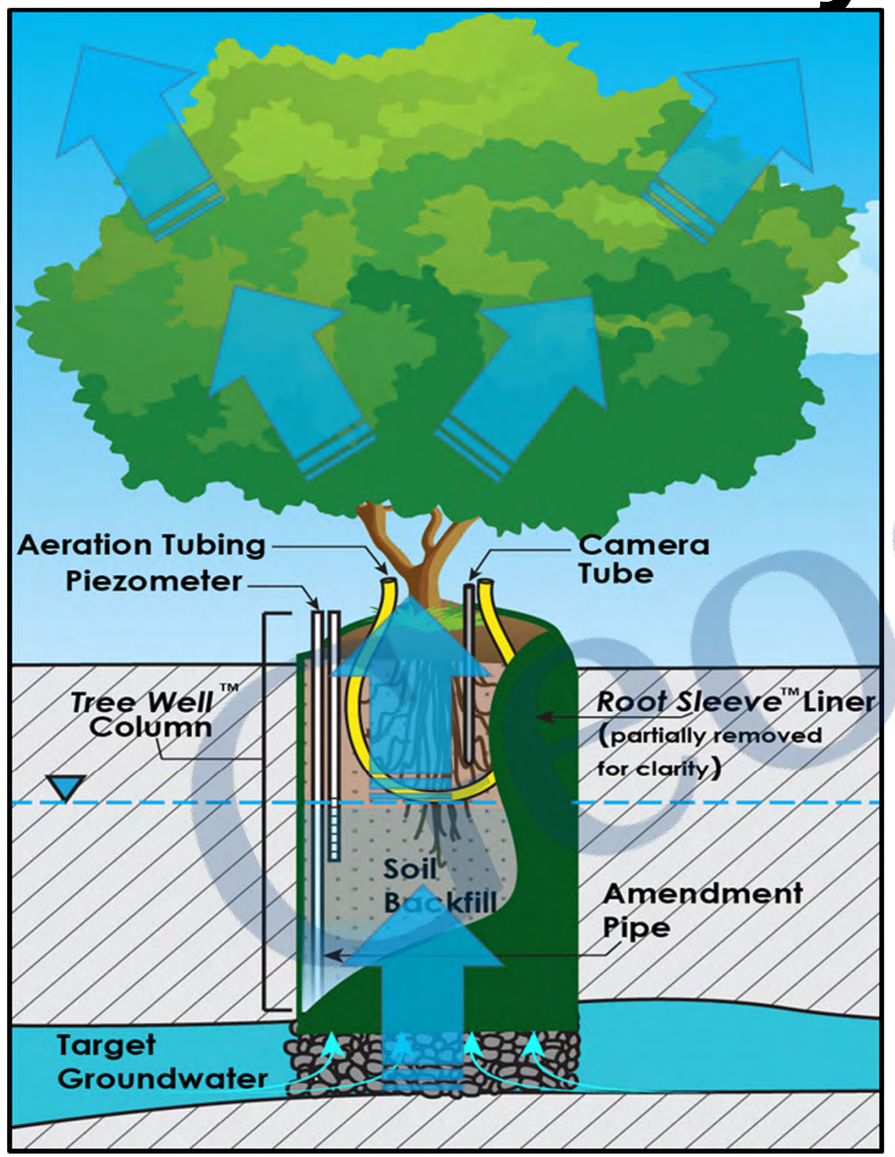
Root_Sleeve™ liner (the "well casing") excludes non-target zones and surface water infiltration

A constructed phytoremediation system that targets a specific GW zone for remedial effect. Patented and designed by Geosyntec's partner firm ANS.

Applied at over 100 sites

A hydraulic connection is established between plant roots and target groundwater, enabling the system to provide plume capture/hydraulic control.

The *TreeWell* System: Key Benefits



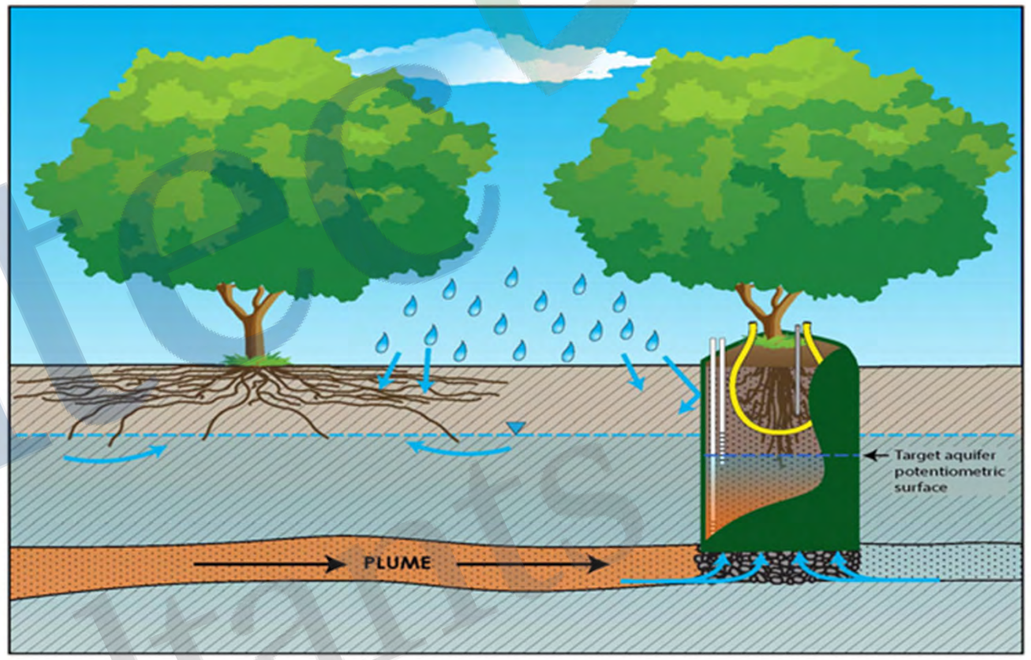
- Highly adaptable – can be tailored to specific site conditions
- Effectively treats a wide range of contaminants - organic and inorganic
  - Including some emerging contaminants: 1,4-dioxane & 1,2,3-TCP
  - Potential for PFAS
- Optimizes growing conditions; Mitigates phytotoxicity
- Pre-treatment option (reactive treatment media – ZVI, etc.)
- Hydraulic control typically achieved within 3 to 4 growing seasons
- *Active* treatment – delivered in a *passive* manner
- ***Green & Sustainable***: solar-powered remediation, minimal O&M, resiliency through system design and plant selection
- Accepted as a proven and effective remedial alternative by EPA and various state agencies

It is a designed, engineered approach to using plants to address contaminant issues.

Why Use an Engineered Phytoremediation System?

Limitations of Conventional Phytoremediation

- Target groundwater too deep
- Site soils too poor, too compacted
- Contaminant concentrations too high
- Reliance on precipitation



Benefits of Engineered Phytoremediation using the *TreeWell* System

- Control plant growth, manage site conditions and target the zone of remedial effect
- For GW as deep as 50’ bgs (or more)
- Treat high contaminant concentrations
- Can reduce the time to meet remedial goals
- Allows plants to ***thrive***

Risk Management Considerations

Requirements for Phytoremediation Success

Vegetation

- Must thrive under site conditions (prioritize natives; beware of exotics)
- Must utilize targeted water

System

- Must create remedial effect
- Must ensure that the fate of the contaminants does not create additional problems (e.g., leaf accumulation of contaminants)

vs.

Reasons for Phytoremediation Failure

- **Lack of phyto-specific site data**
- **Wrong application for site conditions or poor design**
- **Poor planting techniques**
- **Poor operation/monitoring**
- **Unrealistic expectations**
- **Use of unsuitable plant species**

Case Study 1: TreeWell Phytoremediation at Danville, IL

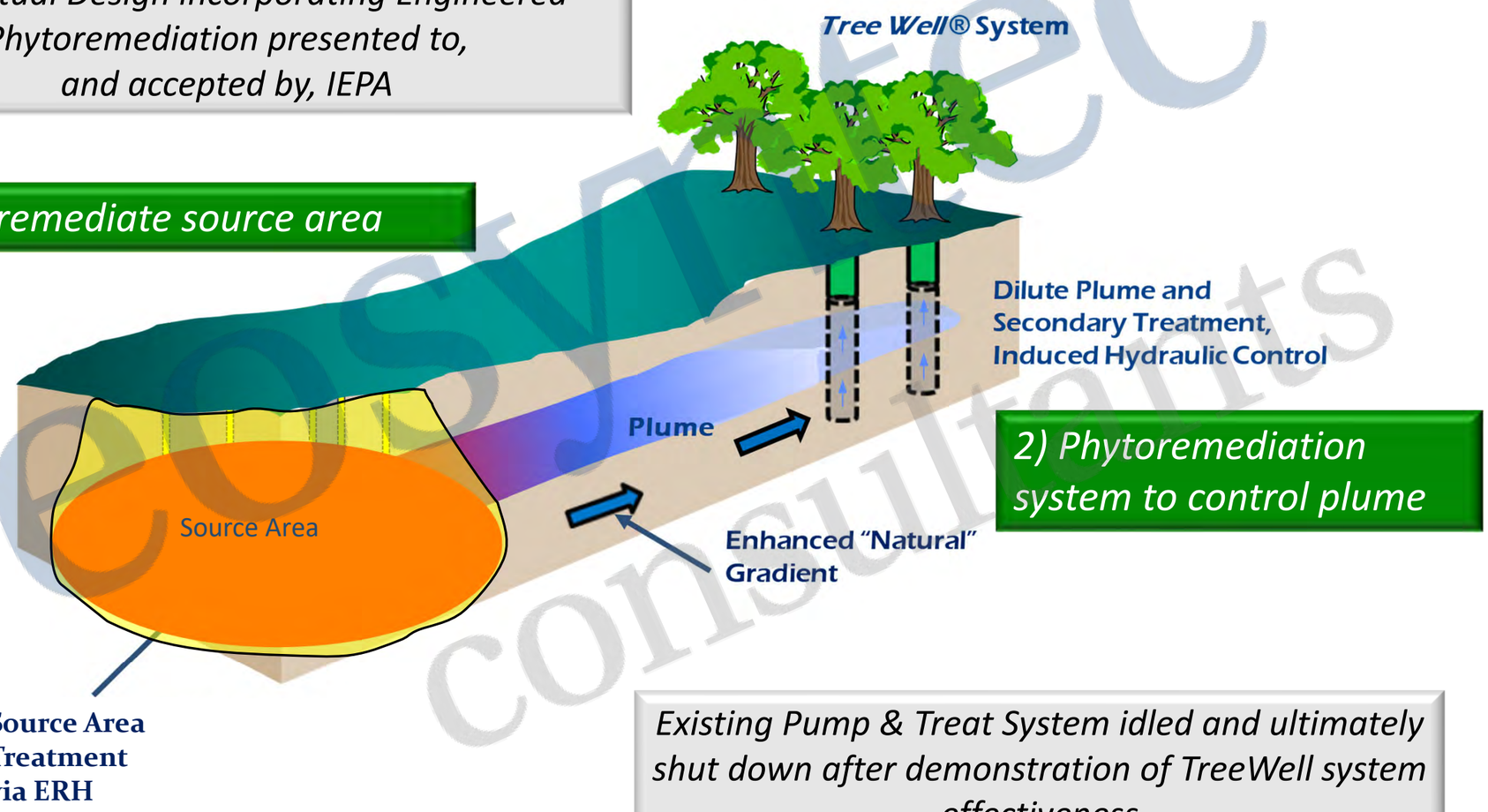
Background & Summary

- Manufacturing facility in Danville, Illinois
- Carbon Tetrachloride plume with DNAPL
- Primarily low K glacial till with sporadic sand zones
- Existing P&T system very inefficient, expensive (required batch operation)
- *TreeWell* phytoremediation system installed in 2015
- **IEPA approved disabling P&T system in 2016; now abandoned**

Danville - Conceptual Design for Integrated Remediation

Conceptual Design incorporating Engineered Phytoremediation presented to, and accepted by, IEPA

1) ERH to remediate source area



2) Phytoremediation system to control plume

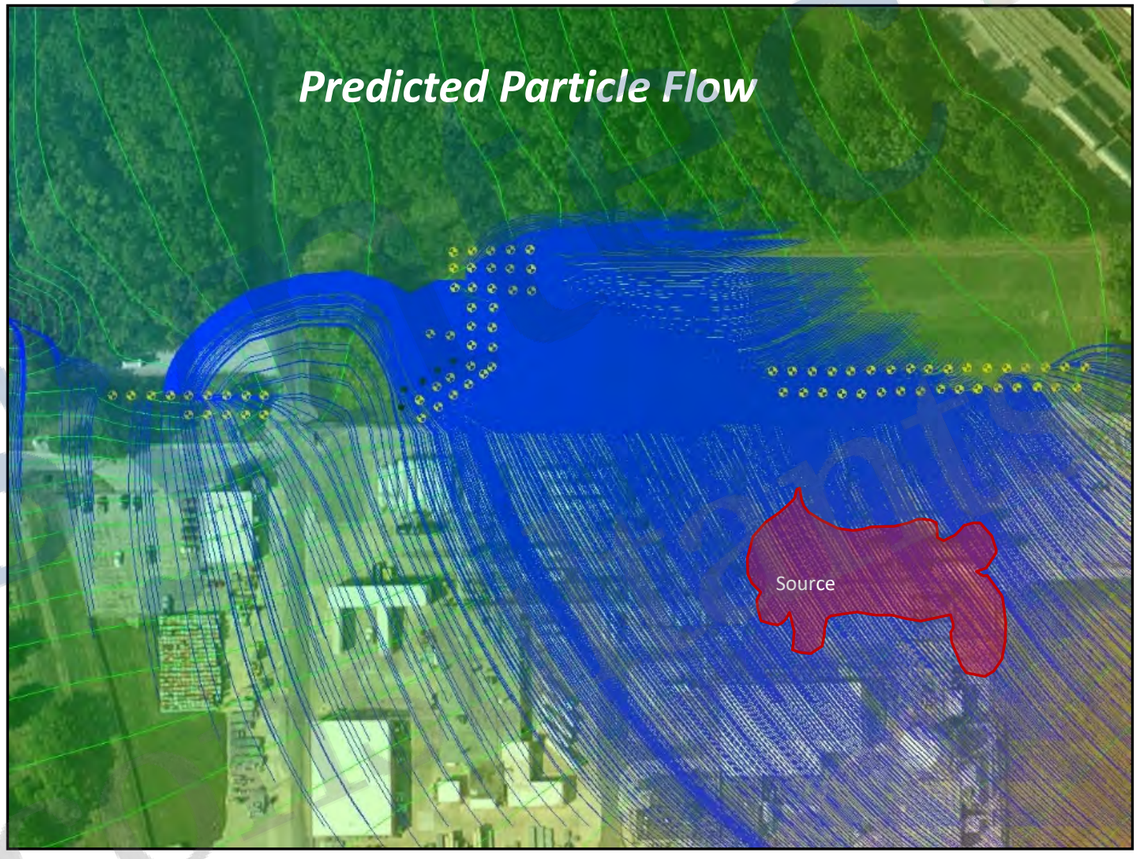
Existing Pump & Treat System idled and ultimately shut down after demonstration of TreeWell system effectiveness

Modeled Groundwater Flow

Initial groundwater modeling performed prior to system installation

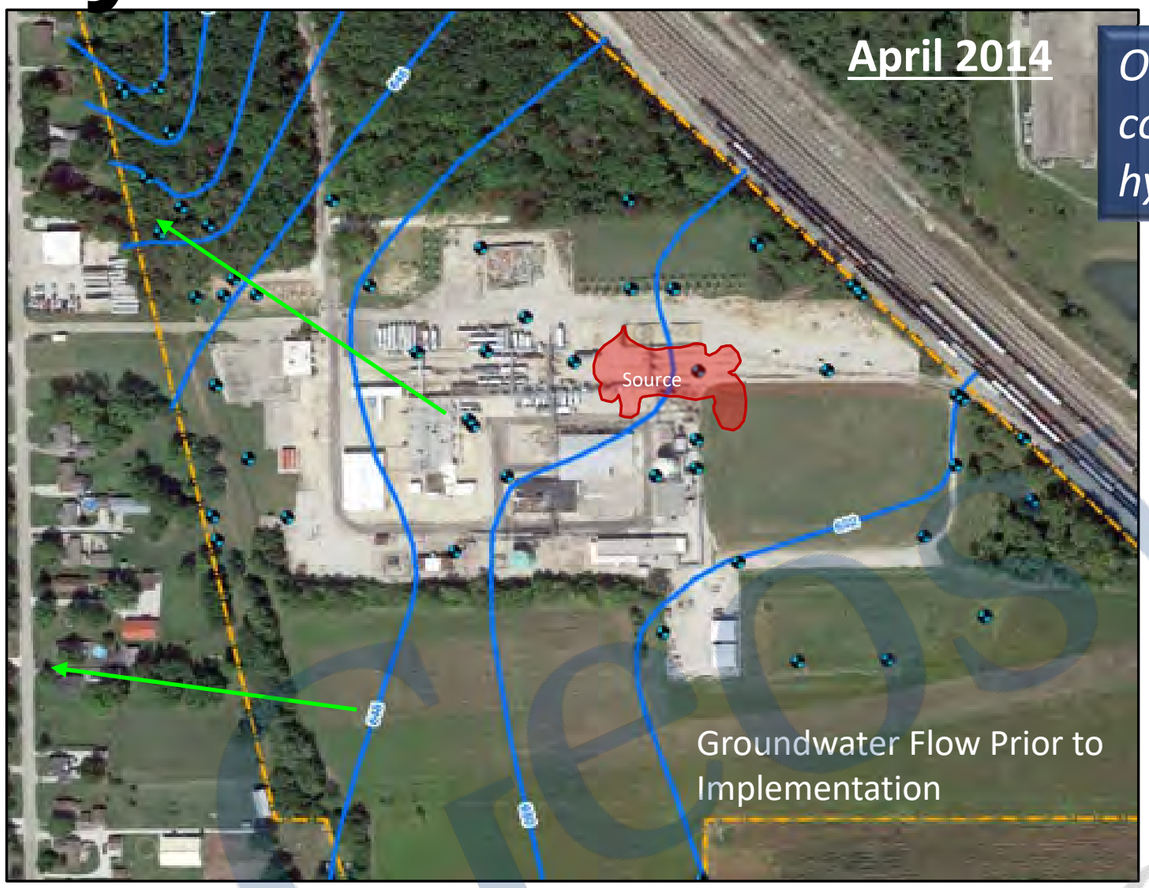
51 TreeWell units installed in 2015; additional 28 units in 2017

Excellent correlation of model predictions to observed hydraulic control

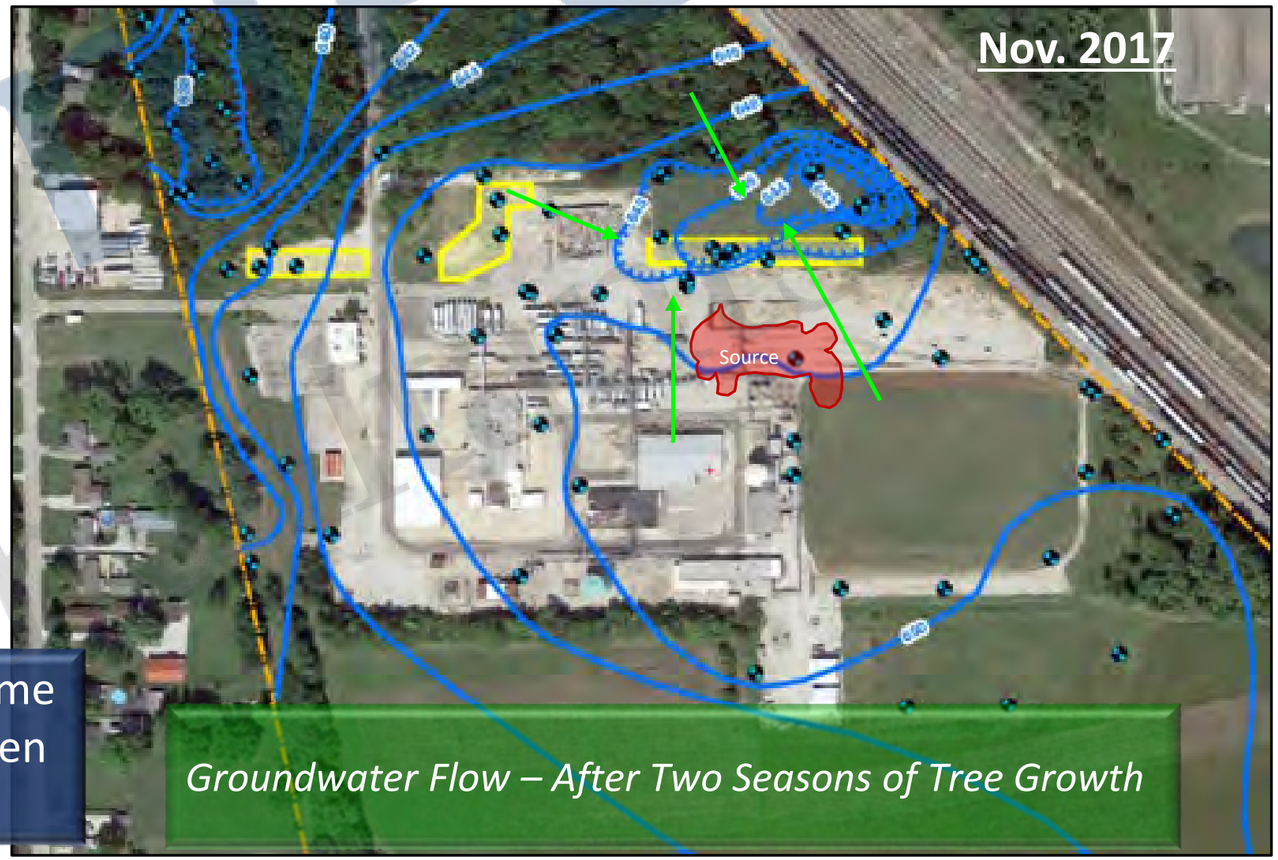


And here's what happened…

Hydraulic Control of CCL4 Plume

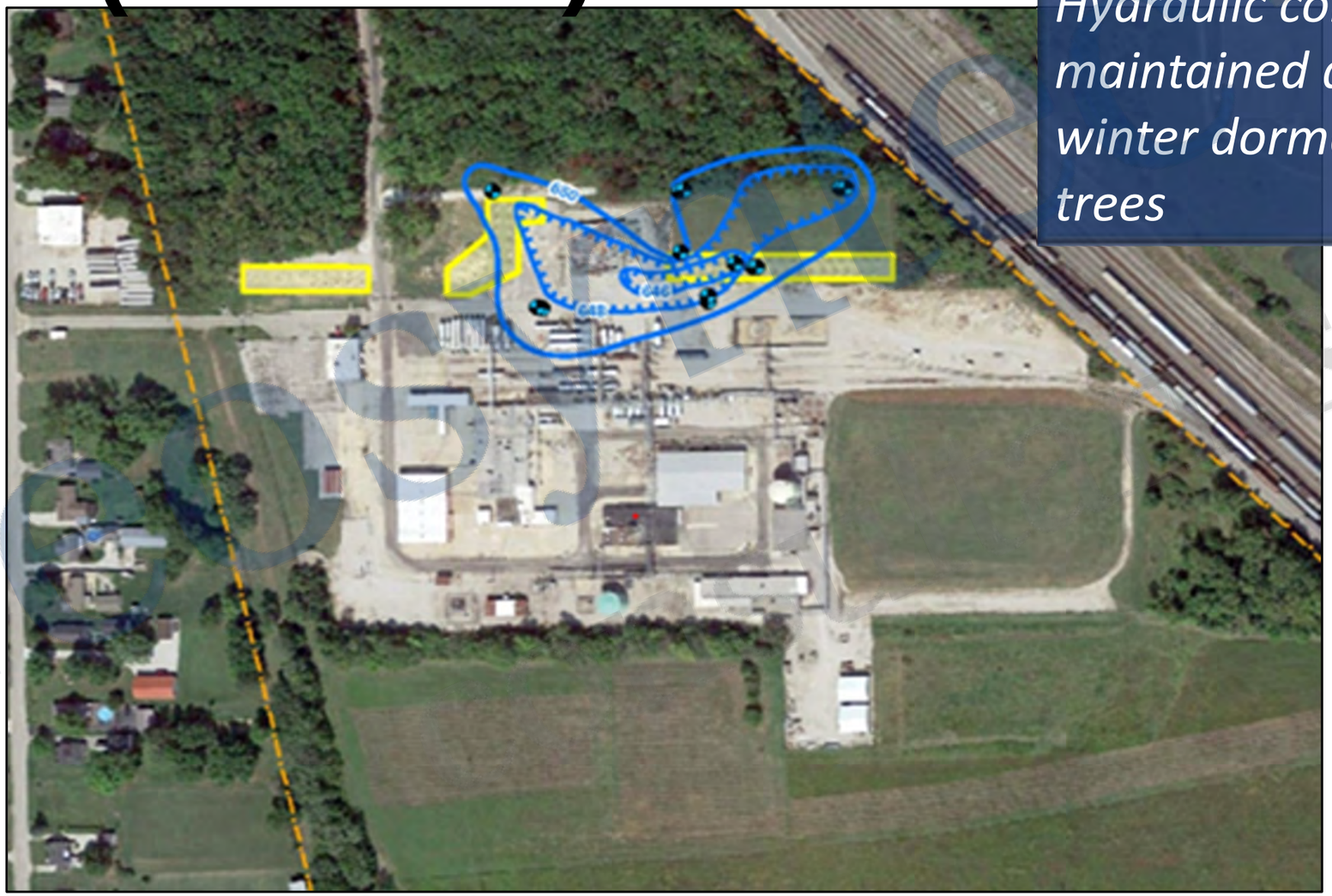


Original P&T system – source control without plume hydraulic control



TreeWell units capturing plume and hydraulic control has been established

Hydraulic Control Maintained Through Mid-Winter (Feb 2018)



Hydraulic containment maintained despite winter dormancy of trees

Comparison of Phytoremediation vs. P&T

Pump & Treat (Source Containment) System
Operational Years (1980 – 2016)

100,000 Gallons per year – estimated maximum removal rate of groundwater or average of < 275 gallons per day (GPD) (<0.2 gpm)

Five pumping wells in operation - no significant/observable groundwater hydraulic influence (2013-2016 period)

$75K - Average Annual Cost (approx). of O&M 2013 - 2016 (excluding treatment and groundwater monitoring)

P&T System was ineffective

System idled in 2016 during proof of concept/pilot of Engineered Phytoremediation System

Engineered Phytoremediation

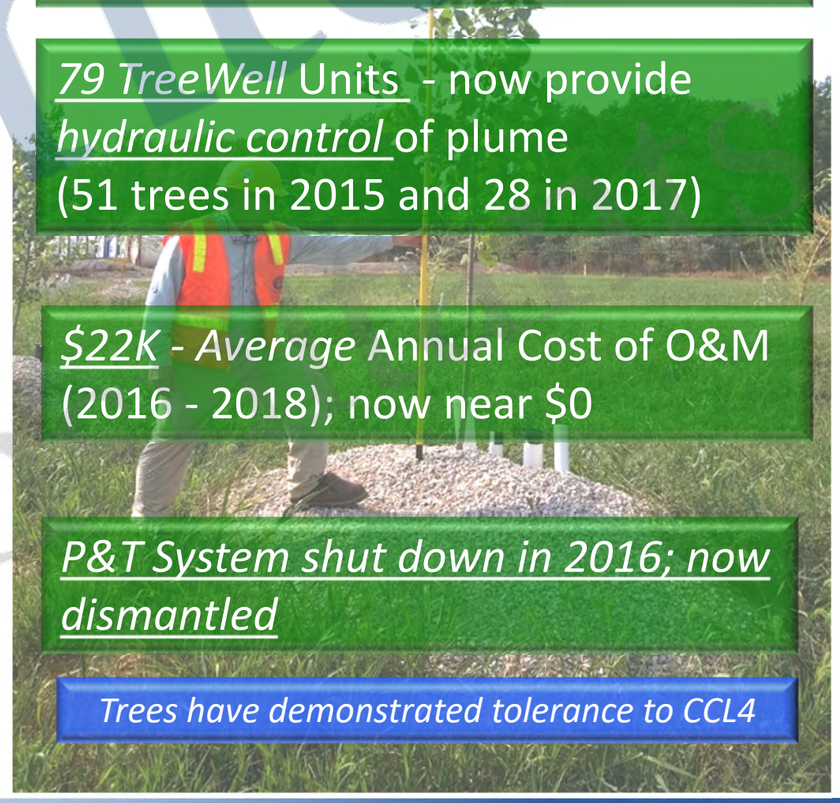
>1,00,000 gallons per year is estimated current extraction rate via engineered phytoremediation (3 gpm +/-)

79 TreeWell Units - now provide *hydraulic control* of plume (51 trees in 2015 and 28 in 2017)

$22K - Average Annual Cost of O&M (2016 - 2018); now near $0

P&T System shut down in 2016; now dismantled

Trees have demonstrated tolerance to CCL4



Results To-Date Summary

The *TreeWell* phytoremediation system has:

1) Obtained hydraulic control of the plume in just two growing seasons;
2) Enabled abandonment of the P&T system; and
3) Received enthusiastic endorsement by IEPA

Next Steps…

- Complete the ERH remediation at source area
- IEPA goals will then have been met
- *Apply for conditional closure (anticipated in 2020)*

Case Study 2: Sarasota, Florida

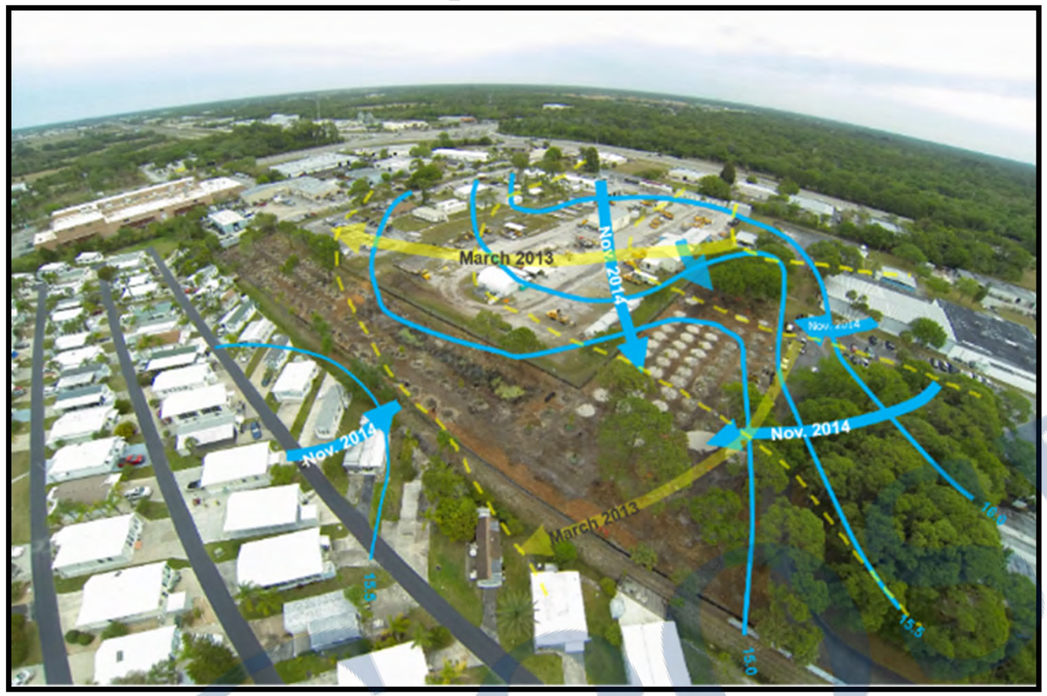
Site Background

- Manufacturing facility in Sarasota, Florida
- CVOC, 1,4-dioxane and arsenic groundwater plume in fractured bedrock
- Initial remedy: Long-term pump & treat system with UV/Peroxide
  - >$300K/Year O&M costs
  - >20 Years to meet Remedial Goals

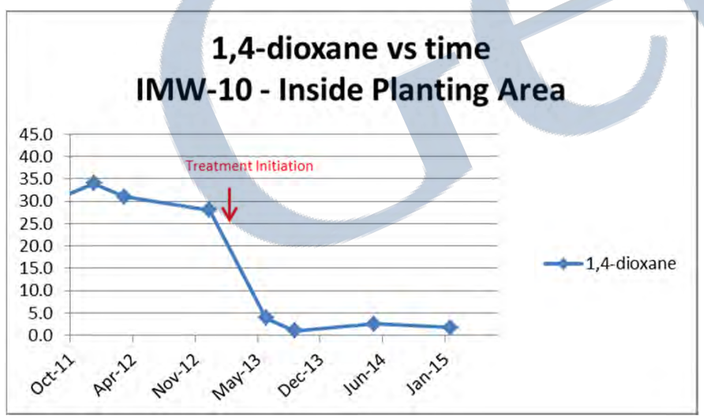
Geosyntec's *TreeWell* System Installation & Outcome

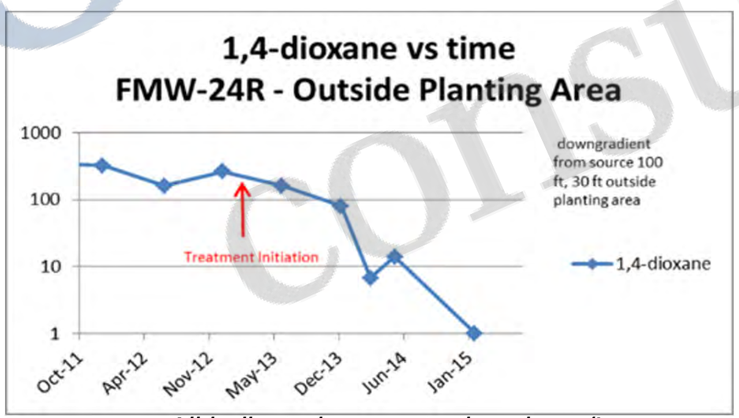
- 154 *TreeWell* units planted in 2013
- Planted four native wetland species – eliminated permitting reqmts.
  - Restoration of distressed wetland (removal of invasives)
- Cost to implement: about the same as one year's O&M for the P&T system
- Hydraulic capture demonstrated by 2014; P&T system idled and later dismantled
- Groundwater concentrations significantly reduced

Sarasota, Florida



- Comparison of GW flow at time of *TreeWell* system installation (Yellow) vs. 18 months post-installation (Blue)
- Gradient reversal in only two growing seasons
- Experience at Sarasota with predicted groundwater response versus actual has been applied to modeling of other sites with similar success



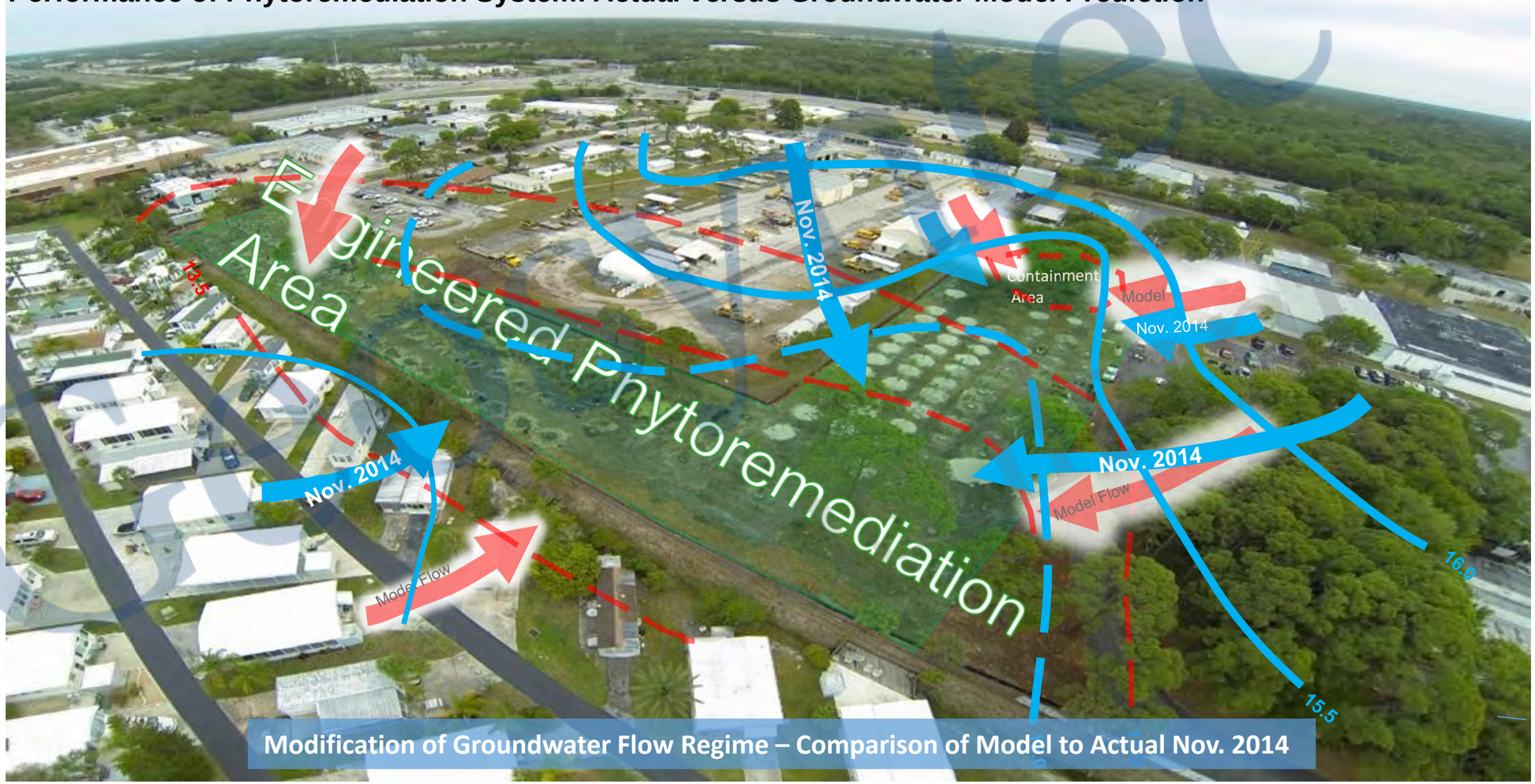


Dissolved-phase concentrations have decreased significantly and rapidly since implementation

All indicated concentrations in µg/L

Sarasota, Florida
Modeled vs Actual Groundwater Flow

Performance of Phytoremediation System: *Actual versus Groundwater Model Prediction*



Modification of Groundwater Flow Regime – Comparison of Model to Actual Nov. 2014

Sarasota, Florida
Modeled vs Actual Groundwater Flow

Performance of Phytoremediation System: *Actual versus Groundwater Model Prediction (cont'd)*

Comparison of Feb. 2016 to Modeled Flow

Sarasota, Florida

In other words, an ineffective and costly P&T system was replaced with effective, low-cost phytotechnology…

Resulting in:

- *Significant savings to the client*
- *A happy client **and** regulator*

No Further Action granted in 2016;

Site Closure (a *Site Rehabilitation Completion Order*) issued by FDEP in March 2019

Summary of Phytoremediation Technology: Key Benefits

- Plant-based remediation technology can be very effective for site cleanup when designed and implemented correctly
- Highly **adaptable** to specific site conditions and contaminants
- Applicable to some emerging contaminants (including possibly PFAS)
- Applicable to many sites: cold climates, dry climates, deep and/or confined aquifers, sites with covers/caps, etc.
- Potential of **significant cost-savings** over conventional treatment options: Typical TW Unit cost = $2,000 to $5,000
- Great ***alternative to P&T*** systems
- **Green & Sustainable** technology
- Well-accepted by regulatory community
- Numerous secondary benefits

Thank You

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***TreeWell* Technology Information:**
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